AN EXPLORATORY ANALYSIS OF THE POTENTIAL USE OF AUGMENTED REALITY IN AIRCRAFT MAINTENANCE

THESIS

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Abstract

During the last decade manpower constraints and an aging fleet, along with sustained war time operating tempo, have combined to place a significant strain on the Air Force maintenance community. Recent technological advances have enabled Immersive Technology to be applied to industrial applications in the commercial sector. This has sparked interest within the Air Force and generated various initiatives seeking to enhance readiness through the application of Immersive Technology. This research explores how Immersive Technology can be applied within the maintenance community. Semi-structured interviews were conducted to determine where the maintenance community shortfalls exist, if the available technology has the potential to meet those needs and what challenges need to be addressed prior to implementation. The findings of this research are used to produce recommendations for the maintenance community.

To my wife and children, thank you. Without your love, support and patience, this entire

process would not have been possible.

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I sincerely appreciate the guidance and insights of my faculty advisor, Maj Tim Breitbach and committee member Maj Ben Hazen. I would, also, like to thank my sponsors from the Air Force Research Laboratory, Pamela Kobryn and Capt Dave Eisensmith, for all of their support.

Richard B. Keesling

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AN EXPLORATORY ANALYSIS OF THE POTENTIAL USE OF AUGMENTED REALITY IN AIRCRAFT MAINTENANCE

I. Introduction

Background

In response to congressionally imposed budgetary constraints, the United States Air Force (USAF) completed a significant force reduction initiative in 2014 (Woody, 2017). One of the areas hardest hit was the aircraft maintenance community. At one point in 2015, the USAF was short approximately 4,000 maintainers. The reduction in manning has been further compounded by a consistently high operations tempo and an aging fleet (Losey, 2017). This has left a force that is undermanned, overtasked and undertrained. As the community attempts to rebuild, the workforce has been flooded with apprentice level technicians which has created additional problems.

In the past, it was typical to assign a 7-level maintainer to oversee work being done on each broken aircraft. After the drawdown, it is not uncommon for senior maintainers to be required to manage repair work on anywhere from 2 to 4 aircraft simultaneously (Losey, 2017). Figure 1 compares the breakdown in manning between overall maintenance manning levels and two of the career fields most impacted by the shortage between the start of the drawdown in 2013 thru 2016: crew chiefs and avionics technicians assigned to tactical aircraft. Notable in this figure, while the overall manning levels during this period have remained around 95%, the crew chiefs and avionics career fields are 5-10% lower. This disparity becomes more evident in the second and third graphs which break the manning levels down by skill level.
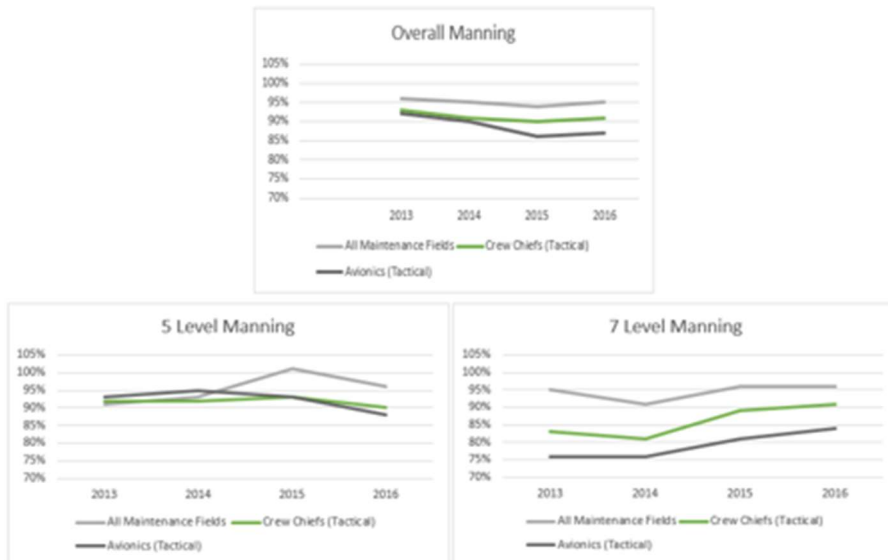
Figure 1. Manning Data from 2013-2016 (Losey, 2016)

This state of affairs has stretched resources thin by placing heavy reliance on less experienced technicians and potentially reducing the quality of work being accomplished. The consequences of this appear to be manifesting as aviation mishaps are on the rise. Figure 2 shows that between fiscal years 2013 to 2017 incidents have increased by 40% despite a decrease in hours flown, see Figure 2 (Copp, 2018b). In 2018, the DoD experienced 11 aviation mishaps resulting in fatalities (Copp, 2018a; Losey, 2018). While multiple factors are responsible for this trend, several incidents have been attributed directly to maintenance.
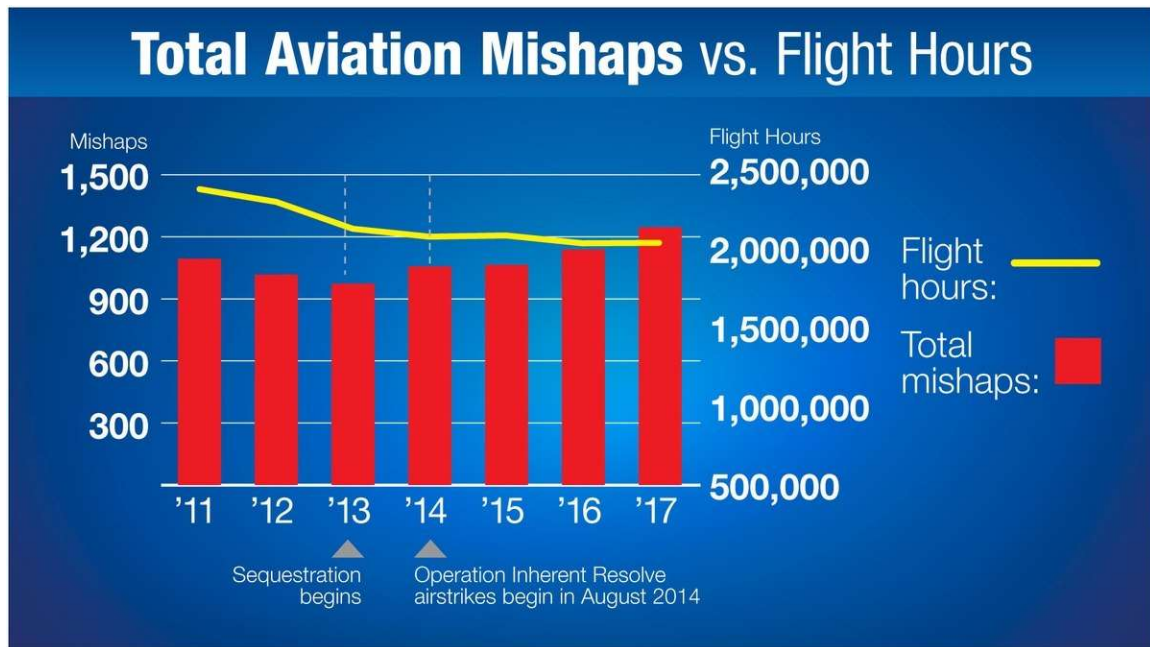
Figure 2. DoD Aviation Mishaps (Copp, 2018b)

The current manning constraints have a large impact on training as well. The technical information used to accomplish maintenance tasks are instructions that are not necessarily instructive. For example, an aircraft task might say, "place chalks next to tires." To an experienced technician, it is clear that the chalks need to be placed in a manner that will prevent the aircraft from rolling. However, this intent is not spelled out and might not be interpreted correctly by an inexperienced maintainer. This context gap has traditionally been filled by pairing inexperienced maintainers with seasoned technicians for on-the-job-training (OJT). However, there are not enough seasoned journeyman and craftsman to provide adequate training (Woody, 2017).

Commercial Approach

Over recent years the commercial industrial sector has been facing a manning crisis of its own. U.S. manufacturing job openings are quickly outpacing the supply of

qualified candidates, resulting in a growing gap in the industrial workforce. A 2015 Deloitte study estimates that there will be three and a half million manufacturing jobs available over the next decade in the US, two million of which will go unfilled (Abraham and Annunziata, 2017). One of the conditions contributing to this state is the skills gap between job requirements and the available labor pool. Traditionally, workers for these positions were hired with some form of basic skills that were built over time by a system of specialized and on-the-job-training. There is a case being made that Augmented Reality (AR) can be used to harness the institutional knowledge that traditionally takes years to accumulate under the current method and package it in a way that a user with minimal experience and basic skills can utilize. To this end, companies such as Boeing, GE and others have begun initiatives exploring ways to leverage Immersive Technology to assist with the deficit. Initial findings from these efforts seem to show promise.

Leadership Perspective

In a speech given at the 2018 Air Force Association Air, Space and Cyber Conference outside Washington, D.C., Air Force Secretary Heather Wilson acknowledged the demand on the Air Force to be greater than it is sized to support. She announced the service's intention to expand capacity by adding more than 70 additional squadrons. Included in this list are 5 bomber squadrons, 14 tanker squadrons, 7 special operations squadrons and 1 airlift squadron (Pawlyk, 2018). For this plan to come to fruition, even greater demand will be placed on the maintenance training infrastructure to generate the manpower needed to support the additional operations.

The Air Force is being pushed to find more innovative ways of doing business. In a 2017 speech at Mildenhall AB, Secretary Wilson made the following statement, "What

kind of an Air Force do we need in 2030, and how do we start ourselves on the process of getting there? We are a service whose roots and history are very deep in innovation, and I want to make sure that we're not losing that…" (Insinna, 2017). Additionally, the 2018 National Defense Strategy objectives include sustaining joint force military advantages, continually delivering performance with affordability and speed as well as establishing an unmatched 21st century National Innovation Base that effectively supports DoD operations (Mattis, 2018). Reliance on standard practices to transition the maintenance community from the current state of recovery into the force posture needed to meet the leadership's vision is not feasible. Innovative technology and other force multipliers must be leveraged in order for the Air Force to apply its resources to successfully meet the evolving mission.

Research Objectives and Questions

The purpose of this research is to explore: How AR cam be implemented into the Air Force maintenance community? In order to answer the overarching research question, this research seeks to answer are what are the current shortcomings within the maintenance community and are they good candidates for an AR solution? Is AR better suited to the training or operational environment? What challenges need to be addressed in order to implement an AR solution?

Overview

The following chapters will seek to answer the research questions through a review of the literature defining Immersive Technology, the resource-based view, and other relevant research. Interviews were conducted with members of the maintenance community who are potential users or advocates of the use of AR, AR content providers

and stakeholders from organizations who have experience using AR in some form. Analysis of the interviews will generate data used to build the findings that show where the maintenance community's needs lie, whether or not AR is capable of addressing said needs, and how well the community is postured to support implementation of an AR solution. Finally, the thesis will conclude with recommendations on how AR may be utilized by the maintenance community.

II. Literature Review

Chapter Overview

The following chapter covers an analytical review of the literature surrounding the desired research objectives. Currently, there is a gap in the literature in regards to how immersive technology should be implemented in aircraft maintenance and maintenance training within the USAF. No prior examples of a qualitative approach to this problem were found. by the researcher; instead,The majority of AR literature utilizes is experiments focused on assessing AR against standard practices.

Immersive Technology

As with many developing technologies, there is not one single stand-alone or all-encompassing definition of the AR or Immersive technology. Immersive technology is also referred to as expansive reality (XR). These are two umbrella terms that encapsulate the spectrum of technologies used to deliver information by emulating the physical world through the means of digital or simulated content (Rouse, 2017). These technologies are: Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR).

Virtual Reality (VR) is a set of technologies used to create a fully immersive computer-based simulated environment where the user can only see the computer-generated world and virtual objects (Rouse, 2017). VR typically provides auditory and 3-D visual feedback to the user through a helmet type device. As with most technologies, VR is available in varying levels of complexity. Simple VR systems utilize gyroscopes and other motion detectors to detect head movement but do not permit the user to walk around the virtual environment (Strickland, 2007). More advanced systems can track a

user's movements allowing them to move through and interact with the virtual environment. VR was developed as a gaming platform, but it is being utilized to generate virtual training environments. This can be particularly useful when constraints exist that limit access to the actual item for which training is required. Because the user is completely enveloped in a virtual environment, VR is not a feasible platform for operational point of maintenance, use. Additionally, because the experience is entirely artificial, VR content is difficult to create. Significant amounts of coding is required to generate a realistic environment (Strickland, 2007).

Augmented Reality (AR) is a technology that utilizes wearables (smart glasses) or handheld devices (tablets, smartphones) to project virtual information onto the actual environment. This is the distinguishing difference between VR and AR. Where VR replaces reality, AR enhances it (Del Rowe, 2017; Porter & Heppelmann, 2017). It has the ability to place information in the user's field of view for wearable systems or applies virtual geographically-attached notes on handheld systems. Necessary information can be displayed so the user can view it hands-free (e.g., PDF technical data floating in front of you hands-free). More complex systems track the movement of the viewing device and place floating notes in relative space to the actual hardware. This makes AR potentially useful for certain maintenance operations. The concept of AR has been around since the 1980s but only recently have the required technologies matured and become readily available, enabling further exploration of its potential (Porter & Heppelmann, 2017). At the core, AR transforms volumes of data and analytics into images or animations that are overlaid on the real world (Porter & Heppelmann, 2015). AR is being used to supplement or replace traditional manuals and training methods.

Mixed Reality (MR) is essentially AR with the additional capability of adding virtual objects into the user's view that can interact with the user and actual environment. The interaction is the key distinguishing feature between AR and MR. Where AR provides a way to present information about a task, MR can act as a guide by pointing out items and/or walking a technician through a procedure. An MR user can walk around and through virtual objects in the same manner as with VR but while seeing the real environment.

Another view of these technologies is the Reality-Virtuality continuum represented by Figure 4 (Milgram & Kshino, 1994). This views the technologies through a spectrum covering everything between the real environment and the virtual environment with all areas in between referred to as mixed reality. This has been adopted by Microsoft to include virtual reality within the spectrum of mixed reality (Schonning; Bray; Zeller 2018).
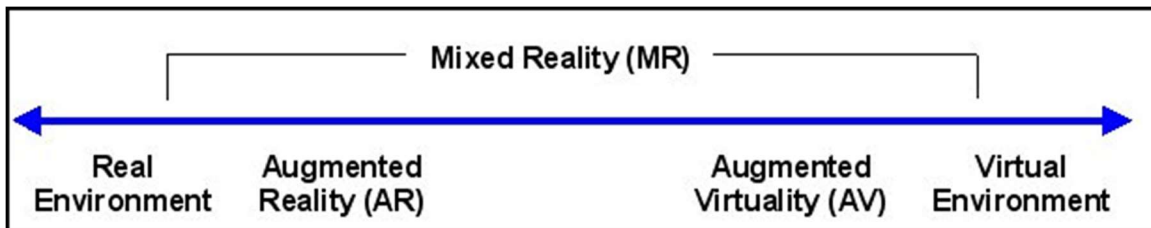
Figure 3 Virtuality Continuum (Milgram and Kshino, 1994)

For the purposes of this study, MR and AR will both be referred to simply as AR. This is due primarily to the fact that a definitive and universally accepted definition does not exist. There are distinctions between the two, but all MR is also AR. Also, it became apparent during data collection that the participants used these terms interchangeably to describe content that was not VR.

The key capabilities of AR's can be categorized in three ways (Porter and Heppelmann, 2017):

- "Visualize": AR can be used to enhance the user's view of the physical world by overlaying 3-D, holographic or X-ray like digital images. Examples of what can be shown are 3-D representations of pumps, lines, conduits, fluid flow, etc. that are not otherwise viewable without significant disassembly. This enhanced view permits technicians to monitor and understand how subsystems interact.

- "Instruct and Guide": Provides real-time step by step visual instructions through a handheld or wearable device.

- "Connect": This capability allows a user to connect to a support service through their device. This remote assistance is similar to commercially available video calling however, 3-D augmented content is able to be added by the remote viewer to guide them through a task.

The traditional method of performing industrial tasks utilizes manuals to provide technical information. This requires people to mentally translate 2-D information for use in a 3-D environment (Porter and Heppelmann, 2017). Depending on the level of complexity, this conversion is not always easy. By superimposing digital information directly on real objects or environments, through either the "Visualize or Instruct and Guide" capability, AR "allows people to process the physical and digital simultaneously, eliminating the need to mentally bridge the two" (Porter and Heppelmann, 2017). Additionally, utilizing the "Connect" capability, a technician and subject matter expert can be quickly linked to a shared view. This enables a level of collaboration and problem solving not currently available through traditional means. The belief is that leveraging

AR will benefit industrial applications by enhancing training quality, reducing the amount required, increasing worker situational awareness, and ultimately reducing error rates.

Resource Based View

The theoretical lens through which this study is viewed is the resource-based view (RBV). RBV is a management theory used to determine strategic resources with the potential to deliver a comparative advantage (Stratopoulos, 2015). Resources are assessed as strategic based on the following criteria: If they are valuable, rare, difficult to imitate and non-substitutable (Szymaniec-Mlicka, 2014).

RBV also divides resources into two categories: tangible and intangible. Tangible resources are assets that can be touched, seen and quantified. Intangible resources are those that cannot be easily touched, seen, or quantified such as the knowledge and skills of employees. Intangible resources are more likely to meet the criteria of strategic resources and therefore, firms should place a premium on nurturing and developing their intangible resources (Ketchem & Short, 2012). Important to the application of this theory is the understanding of the relationship between resources and capabilities. Resources are items that an organization possesses and capabilities are what that organization can do with said resources. This research views a fully qualified technician as a resource. Although the individual is tangible, the skills that are represented in this case are intangible.

The VRIN model, depicted in Figure 5, is a tool used to assess whether or not a resource is considered strategic and therefore capable of providing a competitive

advantage (Szymaniec-Mlicka, 2014). Applying the model to a fully qualified technician produces the following results:

- Is it valuable? Yes. Creating a fully qualified technician is expensive, and there is a time cost. The capabilities produced by the resource are also of value.

- Is it rare? The number of maintainers in the USAF does not initially seem to meet the definition of rare. However, when you compare requirements to actual levels, the argument can be made that, yes, they are rare in the sense that there is a scarcity or shortage of supply versus demand.

- Is it costly to imitate? This category is not relevant in this case. An argument could be made about the ability of a competitor to imitate the resources of the USAF, but that lies outside of the scope of this project.

- Non-substitutable? Currently there is no suitable alternative to a fully trained technician.
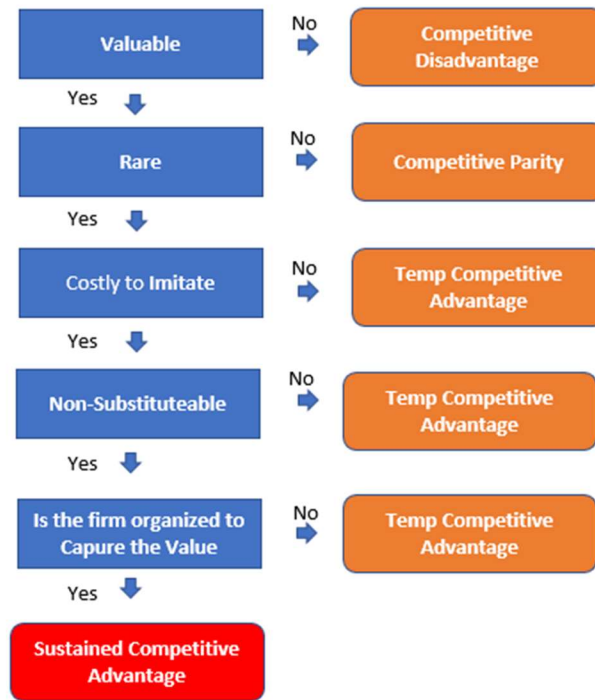
Figure 4 Modified VRIN Model: Adopted from Rothaermel's (2013) "Strategic Management"

This research proposes that a fully trained maintenance technician is a strategic resource. This is further bolstered when the two primary capabilities produced by the resource are taken into consideration: Training of other technicians and operational maintenance actions. Every form of USAF maintenance training relies on qualified technicians. The same could be said for any operational maintenance actions. Technicians who are less than fully qualified are involved in the performance of maintenance, but a qualified technician is required for guidance and acceptance of tasks. Though a single technician may revert back and forth from providing training or operational maintenance, the performance of one prevents the other. Therefore, a maintenance community currently being inundated by unqualified technicians while simultaneously experiencing a

scarcity of the qualified technicians has to make some tough choices about how to manage its resources. Do they cut back on maintenance to provide the training required to increase the level of qualified technicians or cut back on training to ensure mission completion? This research will use the lens of RBV to fill the gap in the research.

Experiment-based AR Research

Academia and the industrial community have conducted numerous studies on the application of AR to industrial tasks. These primarily consist of experiments that fall into one of the following categories: Developing a proof of concept to assess the usability of the technology and experiments that seek to quantify whether or not performance is enhanced by using AR. The results of the research have been mixed.

In a 2017 pilot program GE incorporated smart glasses into a procedure for tightening and torquing fluid fittings on a jet engine (Shay, 2017). They found that the smart glasses prevented the mechanics from having to continually divide their attention between the component being worked and the manual, resulting in reported efficiency improvements ranging between 8-12%.

Similarly, Boeing has tested the use of another headset, the Microsoft HoloLens in its procedure for installing wiring on 767 and 747 production lines. They report a 90% reduction in "first time error rate" ("the ability for a novice trainee with little or no experience to perform an operation for the first time with no errors") and a 30% improvement in task completion time (Boeing, 2018).

Newport News shipyards has utilized AR to inspect ships near the end of their assembly (Porter and Heppelmann, 2017). The AR device is able to scan the ship and superimpose 3-D images to compare the actual ship to a digital model, which identifies

areas of excess material for removal. Prior to this application, engineers had to visually compare the actual ship with 2-D blueprints, a complex, time-consuming process that took up to 36 hours. The new process can be completed in 90 minutes, a time savings of 90%.

A study conducted by Iowa State and Boeing compared the results of three different technical information delivery methods, used by participants to complete a 15-step assembly task. The three methods used to deliver instructions consisted of a desktop and tablet computer loaded with traditional instructions and a tablet with AR-based instructions (Richardson et al., 2014). Relevant areas assessed were task completion time and quality i.e. errors, see Figure 6. For task completion time, no significant difference was noted between the three methods. However, the error rate was reported to be less with participants who used AR. In addition to the overall errors committed, the study broke down errors by task and noted that steps requiring specific placement of parts or selection of specific items from among ones similar, AR's error rate was significantly lower than the other two methods.

In another study by (Mircheski and Rizov, 2017), the visualize capability of AR was applied to end of life non-destructive disassembly of consumer electronics. Certain components of value are targeted for recovery and reuse. However, the 2-D technical drawing currently in use for these tasks is not easily interpreted. This often results in the item targeted for recovery being damaged in the disassembly process. The authors demonstrate how AR could be used to provide animation of optimal disassembly processes, thereby increasing the success rate of component recovery.

An experiment conducted at the Naval Post Graduate School assessed differences in maintenance efficiency and precision were assessed between tasks performed using AR and traditional methods. This experiment found that while there was no significant precision difference between the two methods, AR did demonstrate a significant efficiency advantage over traditional methods (Angelopoulos, 2018).

While validating that a new method will result in reductions in task time and error rate are worthy goals for any organization, viewing/assessing the implementation of new technology through the lens of RBV seeks to find out not what the technology does best but where it should be applied in order to accomplish the most. Specifically, how it can be employed in a way that enhances or expands the capacity of strategic resources in order to maximize a firm's competitive advantage?

The Literature Gap

The literature discussed briefly examined AR and introduced the capabilities of the technology while showing how they might provide value to the USAF maintenance community. Similarly, after reviewing the relevant research it is clear that a gap exists. The experiments conducted up to this point focus on assessing AR against current methods. Although this is important and necessary, this design does not capture AR's ability to provide value in ways that are indirect, intangible or tasks where no capability currently exists. RBV is an appropriate lens for which to explore how AR can be applied to enhance the maintenance community.

III. Methodology

Qualitative Research

A qualitative approach was determined to be the best fit in order to answer the overarching research questions of this study. AR is an emerging technology, and its use in the Air Force maintenance community is mostly conceptual. Minimal hard data exists. According to Strauss and Corbin (1990), "Qualitative methods can be used to determine what lies behind a phenomenon about which little is known." Qualitative researchers typically gather multiple forms of data, such as interviews, observations, historical documents, and other information rather than a single source (Creswell, 2014). The exploratory nature of the research question seeks to answer questions of what, when, how and why.

When considering the use of AR in aircraft maintenance and maintenance training, one must ask the following: What problems need to be solved? Why do they exist? Does AR present potential solutions? How does this technology address the problem? Introducing AR to the maintenance community without having clear objectives grounded in the answers to these questions could lead to confusion and result in implementation of technology being viewed as the end rather than the means to improvement. Viewing this through the lens of RBV helps avoid this pitfall by focusing on the resource in terms of the competitive advantage provided by the capability rather than the capability alone. The data needed to answer these questions is rooted in the experiences of the members of the community. Therefore, a qualitative approach is an appropriate method for assessing the needs of the maintenance community and how AR may address those needs.

Semi-Structured Interview

Creswell (2014) lists observations, interviews, observations and historical information as the primary methods for gathering data for qualitative research. Observations were not feasible during the time allotted for this study. The nature of this phenomena limits historical document availability. Therefore, semi-structured interviews, both face to face and over the telephone were selected. The strength of the semi-structured interview approach is the flexibility it provides the researcher (Kumar, 2014). Specifically, they allow the researcher to ask questions based on responses given as opposed to strict adherence to a script of questions. Open-ended questions can provide a wealth of in-depth information as long as the respondents feel comfortable about expressing their opinions (Kumar, 2014). Due to the wide variety of participants involved in the study, the semi-structured format permitted a broader scope of answers and information than a structured interview, or a questionnaire would have.

The researcher developed the interview questions based on the overarching research question and the subsequent investigative questions provided in Chapter 1. A full set of interview questions can be found in Appendix 1. Interviews were conducted with willing participants who were familiar with either AR or the Air Force maintenance and maintenance training environment. The questions asked of the respondents form the basis of the findings and through a series of steps constitute the input for the conclusions of the research (Kumar, 2014)

Data Collection

The participants chosen for data collection consisted of stakeholders from three groups: The maintenance community, AR content providers and current users, see Table 1. The purpose of the first group was to generate a definition of the problem. This group consisted of stakeholders representing various aspects of the maintenance community: training, policy, operations and research and development. The participants in this group had varying backgrounds and levels of experience. In the selection of these respondents, the researcher intended to leverage the experiences of the participants to identify the shortfalls of the current methods. The expected outcome of interviewing this category was to aggregate common themes in the hope of defining/determining an actual set of specific problems upon which any proposed solution can be evaluated.

Group II consisted of solution providers. These are organizations that in one fashion or another provide AR content. Though all companies sampled are in the business of providing some form of AR, each has a different approach. Some companies offered internally-developed in house solutions while others work as technology integrators who develop tailored solutions by packaging hardware and software developed by third parties. The purpose of this category was to determine what AR solutions were available and to capture the nuances of the various implementation approaches. Understanding these potential links gave the researcher a chance to match the capabilities of potential solutions against the needs expressed by the first group. Category two also provides the opportunity to begin to ask how. For example, if providers have a solution that appears to address the needs expressed by the subjects in Group II, how can it be implemented and what is needed?

Table 1. Stakeholder Groups

Group	Participants
Mx Training	- 373rd TRS Det 12 (3 participants) - AFRL/RX - HAF A4 - 146th MXG
A/R Solution Providers	- PTC - Taqtile - MERC - Avatar
Current Users	- AFIT ENS - King County Waste Water Management - 82nd TRW (2 participants_

The third stakeholder group consisted of AR users. The original concept for this group was for it to consist of established commercial users of AR with the intent of harnessing their experiences to provide valuable insight and lessons learned worth consideration in any future Air Force initiative. Journal articles implied that a population of industrial users existed which was robust enough to support this concept. The researcher was not able to find examples to support this assertion. Not every company contacted responded. Of the companies that did respond, it became apparent that many of the cases presented as examples of successful implementation could more accurately be described as conceptual or promotional proof of concepts rather than actual mature use cases. Therefore, this category was expanded to include relevant experiments and pilot initiatives both internal and external of the Air Force. Participants of this group consisted of members of an Air Force training wing that is currently involved in an initiative to incorporate AR into aircraft maintenance initial skills training. Additionally, a graduate

student who is conducting an AR experiment and a training manager from a wastewater plant that is in the second phase of implementing AR based training are included in the sample.

The majority of the data collection for this study took place in the form of semi-structured telephone interviews. Two were completed in person. Each participant was given details, objectives, and their rights as a respondent prior to begining the interviews. Another way to categorize the participants is two groups (I and III) of AR consumers and one group of providers (II). The similarities between the participants of Group I and III permitted the use of the same questionnaire for both groups. However, unique perspective of Group II required the development of a different set of questions. Each interview was structured with three sections: positioning questions, strategic questions, and open questions. The researcher recorded the interviews which were transcribed either by the researcher or by a contracted third party.

Data Analysis

Once the interviews were conducted, two participants from each group were transcribed and reviewed for the purposes of developing the initial themes. In qualitative research the responses are examined, common themes are identified, the themes are categorized, and the responses given by respondents are classified under these themes (Kumar, 2014). The researcher utilized both Creswell's (2014) methods for accuracy and Charmaz's (2014) and Kumar's (2014) methods to analyze the interview data as follows:

1. Organize and prepare data for analysis

2. Read all of the data collected

3. Code the data

a. Initial coding: Assigned codes to data (text of the interview)

b. Axial coding: Grouped the codes into categories and showed the interconnections between categories

4. Provide an interpretation of the data
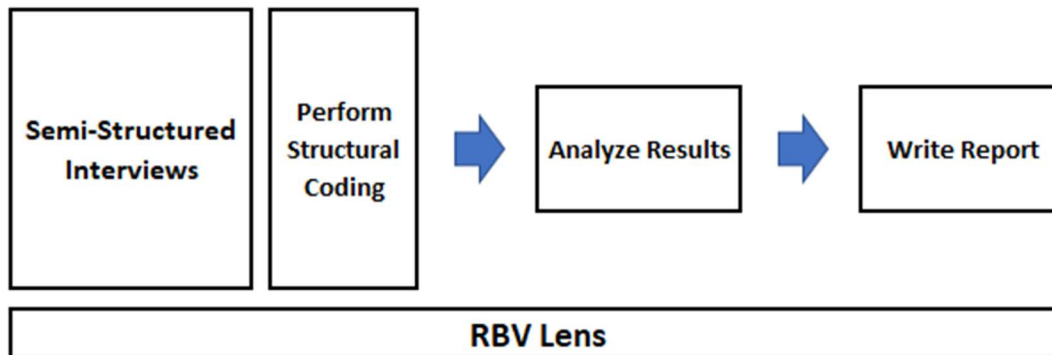
Figure 5. Methodological Flow Chart

To assist with this process, an online qualitative data analysis software called Dedoose was used. Each transcribed interview was uploaded into the program where and coded to tally the number of times participants mentioned a specific code. The Dedoose software provided the ability to compare the amount each code was used or referenced, which enabled a platform to organize the codes into themes. The coding process began with a list of preset codes, with emergent codes added as they appeared. Once the list of codes was complete, everything was re-coded to ensure continuity.

Summary

Exploratory interviews provided the best method for answering how AR technology can aid the aircraft maintenance community. 14 participants were interviewed for the purposes of first establishing a need, second, matching needs to a capability and third assessing the validity of the pairing through the experiences of current AR Users.

The data collected from the participants provided a foundation for answering the research and investigative questions.

IV. Results and Analysis

Introduction

Chapter 4 analyzes the major themes that emerged from the coded interviews. The qualitative data obtained from the interviews is then used to create a framework that will help decision-makers better understand the needs of the maintenance community in regards to the technologies under consideration and where they might be implemented.

Semi-Structured Interviews

After coding the interviews, four major themes emerged: inadequacies of the current method, usefulness of AR, how/why AR should be implemented, and challenges associated with implementation. These themes best capture the responses of the 14 participants throughout the course of the interviews. "Inadequacies with the current method" covers challenges experienced with the current method and opportunities recognized by the participants to leverage AR capabilities to improve or enhance current processes. "Usefulness of AR" captures which of AR's three major capabilities apply best to the participant's challenges. How/why AR should be implemented covers where AR should be implemented, task selection and the expected outcome of implementation. Table 2 portrays the overarching conclusion presented by each group for each corresponding theme.

Table 2. Stakeholder Group Theme Conclusion

	Mx Community	A/R Solution Providers	Current Users
Inadequacies of the current method	Information delivery methods don't provide context. Training aids do not meet needs.	Information delivery doesn't take advantage of digital information.	Deficiencies in training method and training plans
Usefulness of AR	Instruct and Guide were seen as most useful	Connect and Instruct & Guide	Instruct & Guide and Show
How/Why AR should be implemented	In the training realm to replace/augment training aids. To make better use of training time.	Daily use, guidance, harness, share, track information. Increased first time quality	Reduction in errors and better/shorter training
Challenges associated w/ implementation	Network deficiencies and compatibility. Organizational/cultural resistance	Hardware limitations, access to 3D content	Network integration and hardware limitations

The following sections will break down the main results of the coding by group and theme. Tables 3-6 are frequency counts and contain the full results of each group. However, since each group reported different total code counts and did not consist of an equal number of participants, the results have been converted to percentages to present the information more proportionally accurate manner.

Inadequacies of Current Method

This theme captured areas where the participants felt their ability to accomplish their respective missions were inhibited.

Table 3. Inadequacies of Current Method

		GP I	GP II	GP III
Inadequacies of Current Method	Information Delivery	**5%**	**6%**	2%
	Other	4%	0%	2%
	Ancillary Tasks Reduce/Prevent Touch Time	1%	0%	0%
	Cumbersome	1%	0%	0%
	Inadequate Training Plan/Method	3%	0%	**3%**
	Lack of Innovation	0%	1%	0%
	Inefficient Use of Time	1%	1%	2%
	Trainer Shortage	1%	1%	1%
	Training Aid	0%	0%	1%
	Does Not Meet All Needs	**5%**	0%	1%
	Not Possessed	2%	0%	2%
	Unrealistic	3%	0%	1%
	Sum	26%	9%	13%

Group I:

The maintenance community identified two major concerns with the current method. The first was with the delivery method of technical information. The two quotes below illustrate this position.

"When you read the TO, if you are inexperienced, it's actually hard to figure out what they're talking about dimension-wise…for specific bolts there are required dimensions but it's not always easy to tell which bolts are which. It's very easy to make a mistake. They'd be like, "Oh, it's these three bolts, not these three bolts."

"With (aero repair), sometimes you have to rely on your experience. You got to know what to do. A T.O. or a F.I. (Fault Indicator) won't always explain how to do every job or cover every symptom. There's personal experience and institutional knowledge that gets passed down from the people who've been doing it for a while." (Maintenance Community Participant)

Similar instances were brought up by several respondents describing the need to share "war stories" or experiences from the field in order to effectively teach specific tasks. The second concern dealt with the quality of available training aids. The following quote explains the problem.

"Say if we're doing a cargo ramp…We have a training device that somewhat replicates it, but there's obviously inconsistencies between the mock-up and the aircraft…determining what tasks we can train them on, can be one of the big challenges just because it's hard to picture that when you're not actually working on the plane. A lot of people don't get that, so it takes a little bit more time. — which we're actually running into a problem right now because our trainer is broken." (Maintenance Community Participant)

The participants from this group find value in the training devices that are currently possessed by their respective organizations and make use of them for general training. But the aids do not always provide a realistic enough facsimile to demonstrate

complex tasks in a realistic way. Occasionally to help fill in the gaps, operational aircraft are made available for training. However, unless by chance the actual task is required the maintainer's actions are limited to just removing a few panels to enhance visual familiarization in order to avoid breaking the aircraft as the following quote explains.

"If we want to pull a couple panels on the ground trainer (aircraft scheduled for aircrew/maintenance training) and look at a few things we can do that, but we're not going to make any adjustments on that plane because that'll break the jet which could result in it being down for several days for an adjustment that wasn't needed in the first place." (Maintenance Community Participant)

The significance of this inadequacy is there is additional learning that will not take place until the technician is out at an aircraft performing an actual job.

Group II:

Group II consisted of commercial companies that did not have enough familiarity with how the Air Force does business to contribute much to this theme. However, all four of the companies have interacted with the Air Force or have hired former military personnel and seemed to have keyed in on one particular area: the method of information delivery. The quote below not only captures this sentiment but articulates how this could be improved with AR:

"...today, the way that the Air Force conveys this information is a PDF on a laptop, but the individual only has the ability—they just have their reading comprehension to understand how to follow the steps and perform the task. We have that, but then we also give them the other visual aids. That can be the videos and the pictures on how to perform it over the top of the real equipment, There's no confusion when you're pointing to a specific bolt or a specific piece of equipment whether that's the right thing or not. They're not trying to interpret it from written word or a diagram on a page; they're seeing it on the physical piece of equipment. (Solution Provider Participant)

Group III:

Group III consisted of current users. Their most prevalent observation pertaining to this theme were perceived or observed deficiencies in training method and training plans. The quote below discusses one such occurrence and appears partly to blame for a significant incident that occurred at one of the participant's work-center.

"Because of the [incident], it became evident that there were some issues with how we're doing our training, consistency of training, and just our training materials...we've learned that we do a lot of on-the-job training that we weren't capturing, but there was more opportunity to create a more formal and structured training system The old way, you got trained and then you starved, then you trained, then you starved...but are we missing things? Probably because that's why we have some issues with equipment failing or just things that shouldn't be

happening in regard to pumps burning up or things being incorrectly put into

service." (Current User Participant)

Usefulness of AR

This section captured which of the three main capabilities of AR that the
respondents found most relevant or likely to be useful to their respective organizations.

Table 4. Usefulness of AR

		GP I	GP II	GP III
Usefulness of AR	**AR Capabilities**	0%	0%	0%
	Connect	**5%**	**4%**	2%
	Instruct and Guide	**8%**	**3%**	**3%**
	Other	0%	0%	2%
	Visualize	**5%**	1%	**3%**
	Ease of use	0%	2%	2%
	Sum	18%	11%	13%

Group I:

Although it varied across the participants, this group had the least experience with
AR. Therefore, the findings from this section are the results of direct responses and
inferences made by the researcher in response to a stated need or shortfall. Based on the
analysis, the maintenance community seems to have the most significant interest in the
"instruct and guide" capability:

"Number one would be to provide more visual information in video format, if needed, to kind of walk somebody through a job, either a hybrid of a video or using the point-and-shoot feature to add some fidelity to procedures."
(Maintenance Community Participant)

There was also considerable interest in the Connect feature of AR. Multiple participants suggested that the connect feature could be used to dramatically streamline the process of getting assistance from engineers and other support staff not commonly assigned to main operating locations. Others, primarily the ones who identified the shortcomings of their training aids suggested that the Visualize feature could be used to replace or augment the current training aids with digital models that would enable their students to obtain a better grasp of the theory of operation and interaction of components that are otherwise currently unavailable.

Group II:

The solution providers covered all of the respective capabilities but wanted to point out what distinguished their specific solution. They all generally provide the same utility but the main differences emerged in two areas. How they apply the content and what is needed to create content. 3-D computer-aided drafted (CAD) information is commonly needed for creating AR content:

"A new module we have created, it's really focused on training for frontline workers, like somebody that might be on an assembly line or what have you. It doesn't require any CAD information. It's just them putting on a HoloLens, going

about their everyday tasks. It tracks where they are in space. It records their

voices. You could tell if they take a picture. If you'd go through your step and sort

of narrate what you're doing, you're able to go in and sort of tweak things. You

can put in visual cues or videos or pictures or whatever. Rather than me having to

sit there as the subject matter expert and train them every time, I just say, "Put on

this HoloLens. This is going to train you".

The ability to self-generate content, seemingly without special equipment or CAD

drawings makes this solution more user friendly than others offered by the other

providers.

Group III:

The current users were divided evenly between the AR capabilities of "instruct

and guide" and "visualize". In their experience, the two capabilities served two purposes.

First, they had allowed the users to enhance their respective training programs, which

was the primary goal for three of four participants. Second, the users also recognized that

content from these two capabilities possessed the potential of being expanded to

operational use with little or no modification. In the below quote a participant is referring

to how they plan to use content designed for training as operating procedures for some of

their equipment inspections.

"Also, we would have the ability of being more consistent on how people are

doing the checklist. Right now, our paper checklists say, "Check a water pump"

or "Check this piece of equipment," but it doesn't go into detail on what we're

actually checking. This way, we could say, "Check the belts, open the door, do whatever," and they have to go step by step to do that piece of equipment."
(Current User Participant)

How/Why to Implement AR

This theme captured which of the three primary outcomes of AR that the participants found most valuable or expected to realize. It also captured their perspective on AR's suitability for either the training or operational realms. Additionally, this theme provided insights into potential use cases of AR.

Table 5. How/Why AR Should Be Implemented

		GP I	GP II	GP III
How/Why AR Should Be Implemented	**Expected Outcome of Implementation**	0%	0%	1%
	Error rate	1%	3%	5%
	Knowledge Retention	2%	2%	0%
	Other	4%	3%	3%
	Task Completion Time	0%	2%	2%
	Task selection	5%	1%	5%
	Where AR Should Be Implemented	0%	0%	0%
	Operations	1%	1%	0%
	Training	5%	2%	6%
	Why AR?	5%	12%	8%
	Sum	23%	28%	29%

Group I:

The maintenance community consistently believed the appropriate place for AR is in the training realm. For 2 of 6 participants, this is where they saw the best fit. The remaining four would eventually like to see the technology applied to operational uses, but think that the training environment is the appropriate proving ground to address the challenges of integration. They hope AR and other technologies can serve as a force multiplier, maximizing time on task by reducing the time maintainers spent on ancillary tasks (tasks other than direct maintenance). Examples of these are searching for tech data, documenting maintenance, and seeking assistance/sharing information with outside organizations. These concepts are illustrated in the quote below.

"Biggest goal is time on task. I want the maintainer to have more time on task. Accessibility to not only the tech data piece of it but I want to use the HoloLens to snap a picture of whatever they are looking at and being able to translate that to an engineer directly at a depot that can help them right there on the spot. So it's all about time on task." (Maintenance Community Participant)

Others want to enable an increased level of understanding and comprehension by presenting maintainers with a level of information that is not possible with the current method as the quote below points out.

"There's a big push on how people learn differently and obviously, when you can see something or do it yourself you learn a lot better than just reading it off of

some paper. It's kind of that tactile approach of being able to see what's going on

whether it's a virtual 3-D model or even just an embedded YouTube video

showing the task. I think it's just a strong case of how people learn better."

(Maintenance Community Participant)

Group II:

The solution providers pushed all three potential outcomes but were adamant that users would experience a reduction in errors with an AR solution.

"Number one improvement that can be expected is with errors. Mistake reduction

we found it in studies and actuality to be dramatically reduced." (Solution

Provider Participant)

It is important to note that the studies this quote was referring to only support the reduction in "first-time error rate" (the ability for a novice trainee with little or no experience to perform an operation for the first time with no errors). This group also suggested many examples of why an organization would implement an AR solution. Although the examples varied, the root of each was information management. This includes how to gather, create, organize and present both current and new forms of information. The quote below highlights the participant's position on what value can be garnered from his company's information management and delivery infrastructure used to support AR.

Group III:

The connecting thread of the current user's reasons for selecting AR was to improve training. They had previously mentioned adding a layer of consistency and stability to training plans. The group also discussed leveraging AR in a way that completely shifted the training paradigm. They had experienced a reduction in errors to one degree or another relative to the maturity of their respective programs. Additionally, current users are also beginning to find that their training timelines could also be minimized as well. The additional context provided by the digital content, holograms, images, and videos, provides the trainee with a better depth of understanding which reduces the need for closely supervised practical experience. Previously, this was only possible after the trainee became proficient through experience.

> *"The idea that you could take somebody with very little knowledge and have them*
> *operate a system, but operate it consistently and do it correctly each time."*
> *(Current User Participant)*

Potential Challenges of Implementation

This theme captured the participant's concerns about perceived or actual barriers

to the implementation of an AR solution would likely experience.

Table 6. Potential Challenges of Implementation

		GP I	GP II	GP III
	Assessment	1%	0%	3%
	Content	0%	0%	0%
	Access to Digital Content (3D)	2%	4%	2%
	Content Creation	3%	**10%**	5%
	Content Ownership	0%	2%	0%
	Content Storage	2%	3%	2%
	Hardware	2%	**8%**	**7%**
	Learning Curve	0%	4%	1%
Potential Challenges of Implementation	**Network**	**7%**	6%	**9%**
	Organizational	**5%**	0%	5%
	Other	1%	1%	2%
	Recognition	0%	2%	2%
	Reliance on Technology	3%	0%	1%
	Software	0%	1%	1%
	Device Agnostic	2%	4%	0%
	Culture	4%	1%	5%
	Security	2%	4%	1%
	Sum	33%	52%	45%

Group I:

The maintenance community saw the challenges associated with applying commercial AR technology to the government network infrastructure as the as the greatest challenge to implementation see Table 6. For three of six participants, this was based on similar issues they have had implementing different systems such as unreliable or non-existent wireless infrastructure that complicated the use of E-tools. The other three participants had firsthand experience with trying to obtain permission for hosting the technology on the network. One participant, in particular, is in a position constantly impacted by this challenge:

> *"Biggest challenge is the comm community. Everyone's afraid to try out new technology because they don't want to get into all of the security issues. The issue is that A-6 is operating on a set of rules that are archaic." (Maintenance Community Participant)*

Group II:

Having only limited knowledge of government practices, the solution providers viewed the content creation as the most significant challenge, particularly data management:

> *"The ecosystem has to catch up. What's the pedigree of your maintenance data? How is that being updated? If you have a fancy display for crappy data it doesn't really matter. As much or more effort is going to be put into how is the data going*

to be created, transmitted, stored updated all of that as is the ruggedization and

implementation of AR in the field." (Solution Provider Participant)

They also pointed out the unsuitability of the current generation of AR hardware to
operate in the maintenance environment:

"Currently, the HoloLens was designed to be used indoors. It's not well suited for

rugged environments. If you think about a wet or a bright, outdoor environment, it

wasn't designed for that use." (Solution Provider Participant)

Another challenge that was not mentioned often enough to resonate in the coding but
seemed to be a significant barrier nonetheless is the requirement for AR software to use
fiduciary markers such as QR codes to recognize physical objects and link them to any
content that has been generated.

Group III:

The current users fell in line with both Group I and II's concerns over both the
network and hardware presenting the most significant challenges to implementation. The
network challenges are illustrated in the below quote.

"That's really the big hurdle in all of this. None of the systems that we're using to

build AR can go on AFNET. Most of the graphics stuff uses Unity, I think, as the

game engine. Manifest, none of the stuff can actually go onto AFNET, which

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means the content that we build can't go on AFNET, either." (Current User

Participant)

Multiple participants echoed this concern. To get around this, temporary workarounds such as civilian internet have been utilized where available or via wireless mobile hotspots. A fairly thorough list of hardware limitations is captured in the following quote:

> *"The headset has some limitations. Battery power was more limited than I expected, around 45 minutes of runtime on the HoloLens. The headset was rather large and wouldn't be suitable for many of the operating areas. It is also not fluid resistant. It also doesn't work well in bright conditions. The room I conducted the experiment in had a large window. I always made sure the blinds were closed but for one participant I forgot, and they complained that it was hard to see. Once I closed the blinds, they were fine." (Current User Participant)*

Cross Group Analysis

Cross Group analysis examines the coded information for similarities and differences across the three groups. There were multiple instances of agreement between two of the three groups but only one that spanned all three: AR should be implemented in the training environment. Notable areas of difference were observed in the value placed in the specific AR capabilities, and the "expected outcomes of AR". Tables 7 and 8 depict each group's ranked preferences for AR capabilities and expected outcome respectively.

Table 7. AR Capabilities Ranked by Group

AR Capabilities	Group I	Group II	Group III
Instruct & guide	1	2	2
Connect	3	1	3
Show	2	3	1

Understanding which AR capabilities an organization values is important when considering hardware and software for a particular application as not all devices possess the same capability. HoloLens, for example, is capable of supporting all three capabilities as are most applications designed to support it. However, as identified earlier in this chapter, it has other limitations. If instruct and guide is all that is needed, an organization may choose to hardware that is more suitable to their needs.

Table 8. Expected Outcomes Ranked by Group

Expected Outcome	Group I	Group II	Group III
Error Rate	2	1	1
Retention	1	2	2
Task time	3	2	3

The code count for Group I resulted in the following ranking: knowledge retention, reduced error rate and reduced task time. Group II ranked error rate first and had a tie between knowledge retention and task time for second. Group III's results were nearly a match with Group II except improved task time was a clear last. Three of Group I's participants work in the training arena and this may have biased their results towards

knowledge retention. Although there were differences across the top and the middle,
each group rated decreased task time low.

Conclusion

This chapter detailed the coded results and highlighted the prominent themes
portrayed by the three categories of participants. This research identified factors that will
influence how AR can be implemented in the maintenance community. Two definitive
needs emerged from Theme 1: The need for higher fidelity training aids and a better
method of presenting technical information. Theme 2 identified how the participants view
the main AR capabilities. Theme 3 illustrated potential use cases for AR and what
improvement the participants would expect if implemented. Finally, Theme 4 identified
significant potential barriers, the most prominent being network and hardware that will
need to be managed in order to implement an AR solution.

V. Conclusions and Recommendations

Chapter Overview

The overarching objective of this research was to perform an exploratory analysis in order to determine how AR can be applied to the maintenance community. The qualitative data obtained from interviews has provided a basic framework that decision-makers can take into consideration as they move forward with AR initiatives. By examining the data generated from the different groups, decision makers should develop a sense for where AR can best be applied in a way to make the most significant impact and what challenges any initiative will face.

Findings

The purpose of this thesis was to explore how AR could be implemented in the maintenance community. This study identified two current inadequacies within the community: 1) Training aids are either not possessed or do not meet all of the needs, and 2) Inadequate method of delivering technical information. Both of these findings match up with one or more of the basic capabilities of AR.

Identifying tasks where AR can be applied is only one part of determining "how". What actions need to be accomplished to facilitate that implementation is equally as important. For this reason, this study identified a list of potential issues that need to be addressed. The most prominent was related to network infrastructure. This barrier manifested itself in two different ways. First, the software needed to operate AR hardware, as well as generate and manage content, is not currently compliant with the Air Force network requirements. The second network related challenge is the current lack of access to reliable wireless internet. Even if the hosting issues were solved, the AR

hardware is designed to operate wirelessly. Despite past initiatives aimed at installing wireless internet throughout maintenance complexes and flight lines, the coverage at most locations is weak and unreliable.

The next potential challenge to implementation is hardware. According to the participants, the most capable AR headset currently available is the Microsoft HoloLens. However, it was not designed for the aircraft maintenance environment. It is bulky, uncomfortable to wear for extended periods and its ability to display content is compromised by bright environments. Furthermore, it is relatively fragile, not fluid resistant and has a limited battery life. Until the headset technology matures in a way that overcomes these issues, implementation of the technology will be effectively limited. There will be limits to how and where the technology can be effectively restricted. The current method employed by AR software to track and recognize items relies heavily on the use of fiduciary markers primarily in the form of QR codes. These codes are needed in order to connect AR content such as overlays, instructions and leader lines to a piece of equipment. Some companies are beginning to roll out a capability that uses GPS or other location services to reference when it is near an item that has AR content associated with it. However, neither of these methods seem well suited to the operational environment. It does not seem feasible to precisely place markers on aircraft, and the location-based tracking is not possible on equipment that is not stationary.

An additional goal of this research was to assess whether AR is better suited to the operational or the training environment. As identified in Chapter IV, the participants overwhelmingly chose the training environment as where AR should be applied first. Some participants thought this was where the potential benefit was greatest. Others

thought the training environment provided a suitable proving ground for the Air Force to learn how best to use the technology before later implementing it operationally. The constraints induced by the current state of the network, hardware and software challenges support limiting implementation to the training environment.

Recommendations

The available literature speaks to the potential for AR to be a game-changing technology. However, as this research had identified, some significant barriers will need to be overcome before the Air Force can truly consider broad implementation. The current users some of which are performing within the Air Force have developed countermeasures to work around these barriers such as using civilian internet and 4G wireless hot spots. These are not sustainable long-term solutions but are suitable for small unit level projects that can focus on smaller scale, achievable projects while the technology, infrastructure and hardware mature. Based on the participant's responses, the research recommends selecting training locations that have an identified shortfall of training aids and developing 3-D models that can fill that void.

Additionally, the development of a framework can assist leaders with decisions regarding the implementation of AR solutions. The framework shown if Figure 9 is based on the themes that emerged in this study. It can be used by leaders to assess variables associated with a given decision to determine whether or not it is worth pursuing. Inadequacies of the current method can be used to develop a definition of the needs of the community. This definition can be compared against potential solutions offered by providers to asses if they appropriately address the community's needs. Finally, the experiences of the current users can be used to verify the validity of the solution.
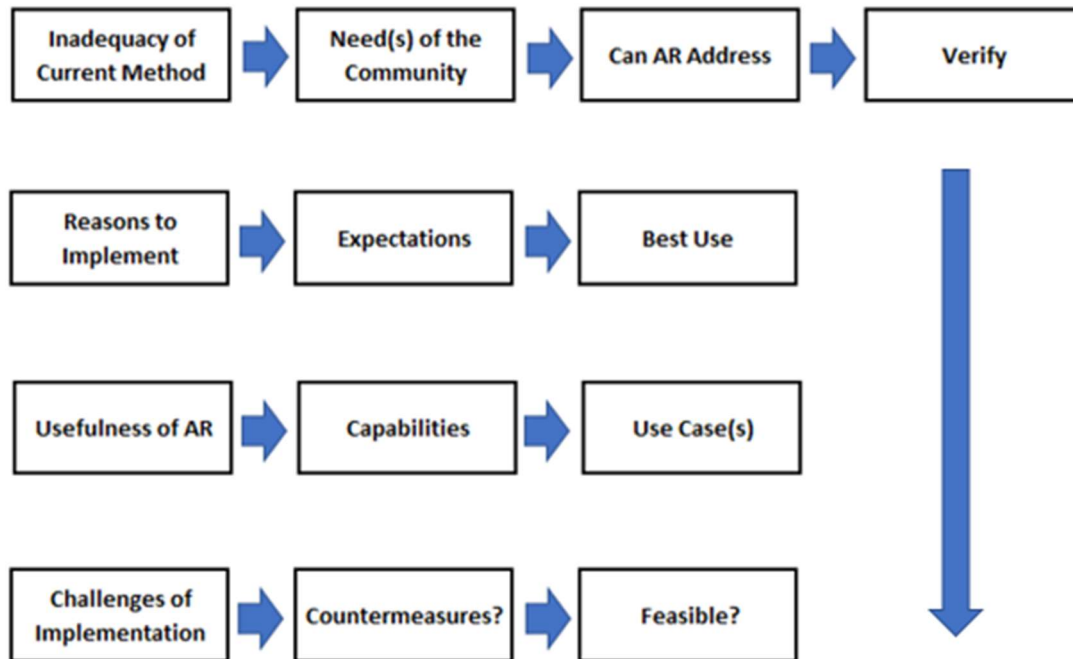
Figure 6. Framework for Assessing AR Potential

Limitations

While this research was exploratory in nature, only 14 participants, representing a reasonably diverse group of organizations, participated in the interviews. The maintenance community in this study was represented by three members from a single training squadron, one participant from the policy division and one maintainer from a C-17 maintenance unit. This group provided valuable information, but their overall makeup is a less than perfect representation of the maintenance community. An approach that captured a more comprehensive representation of the community or one that focused on a specific type of organization at multiple locations might have been able to produce a more robust data set that allowed for additional analysis.

Future Research Opportunities

In order to make future implementation of this emerging technology successful, more research is needed. This study returned a wealth of information but only consisted of 14 participants. Continuation of this study with a greater sample size would add depth to the findings and further address the gaps in the literature. Also, a case study of current users would provide value by capturing lessons learned that could be applied to future initiatives. Additionally, the A-6 community would be well served by a study assessing the relevancy of all of rules and restrictions related to network infrastructure and what can be done to more easily permit the use of commercially available off the shelf (COTS) solutions.

Conclusion

This research aimed to determine how AR could be implemented in the maintenance community. Rather than directly comparing AR against current methods, this study sought to accomplish this assessment by asking the community where its greatest challenges were. Then, the applicability of AR to address those challenges was assessed by utilizing data generated by interviews conducted with AR solution providers and then vetted against the experience of current users.

The Resource-Based View focuses on cultivating an organization's resources and capabilities to better meet emerging challenges (Szymaniec-Mlicka, 2014). The maintenance community faces challenges relevant to managing its manpower and training deficit, both now and into the future. One way to approach this is to improve capabilities. Implementing AR content presents information in a way not currently

possible. Based on the data generated in this study, this capability would directly address the inadequacies identified by the participants in this study.

Perhaps the greatest potential way to enhance a maintainer's strategic advantage is to increase the amount of time they can spend actually performing maintenance. Currently, maintainers spend much of their time on ancillary tasks such as searching for technical information, documenting maintenance actions (manually and digitally), looking up and ordering parts, etc. In the long run, implementation of technologies like AR on an enterprise level in result in many of these processes being digitized and automated. If realized, this would dramatically increase capability which equates to readiness thereby protecting and expanding the Air Force's competitive advantage.

Appendix A, Interview Guide

Interview Guide: Organization Stakeholder

Introduction

Hi, _____, my name is SMSgt Richard Keesling, and I am a Master's Student in Logistics and Supply Chain Management at the Air Force Institute of Technology. How are you doing today?

↺ Thanks for agreeing to talk with me, and thanks for your time. The purpose of this interview is to ask you some questions related to your experience as a (stakeholder) seasoned maintainer and an instructor about implementation/integration of technology and its impact on training effectiveness. This interview is part of my research on the potential use of augmented reality as tool to enhance maintenance training. I would like you to think of it as an open conversation, rather free flowing, about any areas where you think AR could provide a value to what you teach or other areas in general. *It won't take more than 1 hour but less time is of course ok.*

Now, since it is an academic interview, you have some special rights as a respondent:

- All the information you give me today will be treated confidentially.
  - o Your name and your organization's name will not be linked to any answer.
  - o I am having similar discussions with multiple stakeholders in this area, including individuals from other commands, and at the Wing and Squadron level. Any insights or take-aways from our conversation will be reported as originating from the stakeholder group and not a specific person unit, unless you give me permission to do so.
- The interview is voluntary, which means:
  - o You have the right to decline to answer any particular question,
  - o And you can stop the interview at any time.
- I now request your permission to record the interview, if that's OK with you. ↺
  - o You have the right to stop the recording at any time.
  - o The recording will be kept in an encrypted digital file, guarded by me personally.

   o All copies will be destroyed once our research project is complete.

Do you have any questions? ↻ (Answer the questions, if any). Let's proceed.

Positioning questions

1) Can you tell me a bit about your organization's background and primary focus?

 1a) Where you located?

 1b) What airframe(s) do you support?

 1c) Is the training focused just on Airmen assigned to _____ or do you reach a wider audience?

2) *What role do you play in your unit, as in is there a specific area of (instruction)(training)(other) that you are responsible for?*

 2a) How long have you been doing this?

 2b) What did you do before?

 2c) How long have you been in (Air Force)(Industry)?

3) *What methods of instruction/training are used to teach your classes*

 3a) Have you noticed one method that is more or less effective than others?

 3b) How much freedom do you have to tailor your instruction?

 3c) What is required for you to remove/add content or material from your classes.

 3d) Have you done this before?

 3e)Do you use training aids?

  • *Are your available training aids sufficient?*

4) *What are your greatest challenges?*

Focused Questions

1. Are you familiar with AR?
   o How so?

2. Is your organization currently making use of immersive technologies such as VR, AR or MR?
   o In what way?
   o What device/software platform?

**** If yes continue with questions 3-7, if not jump to video and question8****

3. What led your organization to use AR?

4. Where there challenges with implementation?
   o Technological
   o Organizational
   o Human factors
   o Resistance

5. In what way do you develop your content?
   o Internally
   o Externally
   o Via software
   o Coding

6. Has the use of AR resulted in an improvement?
   o How do you measure?
   o What factors are considered?
   o How have your students/employs responded to the introduction of this technology?

7. If you were either starting again or planning to expand the use of AR in your organization, what would you do differently?

• •

8. Having seen the AR demonstration video, can you think of any areas where this technology would be useful

   *** *If need be, prompt with the following questions:*

   o Any areas where this would/wouldn't work?
   o Can you think of any specific area that is particularly challenging either from the instructor or learner's perspective that this technology could improve?

o   Are there certain types of activities that you think this is be appropriate for? Why?

9. Do you think AR would improve training?
o   In what way?

10.   Do you think AR would improve operational maintenance?
o   Why/Why not?

11.   Technology aside, if this became available, what would be required for you to alter the method of instruction.

o   What justification would you have to provide?
o   What level of leadership would need to approve?

12.   What do you think would be the biggest implementation challenges?

13.   In your experience, does your organization structure promote or impedes your ability to innovate?

o   *Are technological advancements in your organization usually top down or bottom up?*

During the course of this conversation, try to move the conversation from the individuals to the organization's overall strategy and how it has positioned itself in the SC / Financing realm. Try to keep it anchored on how financing decisions are made and how the outcomes are measured.

- *For interesting things, ask:* "Tell me more about X".
- *When the respondent is getting vague, ask:* "Can you give me an example of X?" (Especially important for successful or unsuccessful programs or operations. Make sure their definition of success is outlined).
- *If the conversation is getting lost in operational details, ask:* "What is the purpose of this?", *or* "What is the philosophy/idea behind this?"

- *If the conversation is getting too strategic, ask:* "How do you implement this?"*, or* "How do you ensure this happens"*, or* "How do you enable this?"*, depending on the subject.*

Strategic / Open section

(Note: All these questions are optional. Ask only those that seem relevant to the position and that have not been answered before during the course of the conversation.)

Thank you very much for your time and that's pretty much what I had to ask you. The formal portion of our discussion is over, and I'm turning off the recorder.

- o Are there any points you would like to add or do you have any feedback for me? I really appreciate your answers and your time. Would you happen to have any contacts that you think would be interesting in having a similar conversation?

I hope I can contact you with follow up questions after I have analyzed our conversation. I'll send a copy of the interview transcript if you would like to review our conversation. Thanks again!

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14. ABSTRACT
Social media has grown to become a rich source for opinions, authored by individuals who volunteer them, unedited and in real-time. Armed with this information, an organization like the Air Force can understand the perceptions of consumers and learn to better serve the American taxpayer. To accomplish this goal, this research takes a qualitative approach, utilizing social media analytics in combination with various Text Mining methodologies (word frequency, word relationships, sentiment analysis, topic modeling) to provide insight of Air Force related content shared on Twitter. To provide a well-rounded analysis of the overall perception of the Air Force enterprise, the methods mentioned are conducted on Tweets related to the Air Force's five core missions: *Space/Cyberspace, Nuclear Deterrence, Air Superiority, Advancements in Technology,* and *Intelligence, Surveillance, Reconnaissance*. This research also hopes to capture the key players that publish the most engaged Tweets related to the Air Force. By understanding the types of users who possess the most influence (*Regular Users, Bloggers, Celebrities, Military Leaders, Politicians, Professional Organizations*) leaders are better equipped to react to content and protect the Air Force brand.

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